UAT-WP-8-10

DEPARTMENT OF DEFENSE

JOINT SPECTRUM CENTER

ANNAPOLIS, MARYLAND 21402-5064

UNIVERSAL ACCESS TRANSCEIVER (UAT) DATALINK PERFORMANCE AND BIT ERROR RATE (BER) TESTING IN A DISTANCE MEASURING EQUIPMENT (DME) AND JOINT TACTICAL INFORMATION DISTRIBUTION SYSTEM (JTIDS) PULSED RADIO FREQUENCY (RF) ENVIRONMENT

Prepared for

SPAWAR Systems Command

PMW 159 Advanced Tactical Data Link Systems

NOVEMBER 2001

LABORATORY MEMORANDUM #02-770

Prepared by
John Grolle

IIT Research Institute
Under Contract to
Department of Defense

This report was prepared by the IIT Research Institute under Contract DCA100-00-C-4012 in support of the DoD Joint Spectrum Center in Annapolis, Maryland. This report has been reviewed and the information and data it contains is approved for internal JSC/IITRI use.

Reviewed by:

John Grolle	Tom Wright
Project Engineer	Project Manager

UNIVERSAL ACCESS TRANSCEIVER (UAT) DATALINK PERFORMANCE AND BIT ERROR RATE (BER) TESTING IN A DISTANCE MEASURING EQUIPMENT (DME) AND JOINT TACTICAL INFORMATION DISTRIBUTION SYSTEM (JTIDS) PULSED RADIO FREQUENCY (RF) ENVIRONMENT

BACKGROUND

The Universal Access Transceiver (UAT) is a radio datalink system supporting broadcast services – Automatic Dependent Surveillance-Broadcast (ADS-B), Traffic Information Service (TIS-B), and Flight Information Service (FIS-B). The UAT supports two types of messages. The first is broadcast transmissions from aircraft supporting aircraft-to-aircraft or aircraft-to-ground surveillance applications. These include position reports, velocity vector, and other relevant information about the aircraft. This type of transmission is referred to as Automatic Dependent Surveillance-Broadcast mode (ADS-B).

The second type of transmission supported by UAT is the uplink broadcast of information from fixed ground stations. Services that can be potentially supported with this uplink include weather broadcasts and aeronautical information (e.g., status information on navaids, special-use airspace, and uncharted obstacles), referred to as Flight Information Services – Broadcast mode (FIS-B). Other supported services include traffic information broadcasts derived from ground-based radar systems referred to as Traffic Information Services – Broadcast mode (TIS-B).

The UAT testing consisted of Message Error Rate (MER) and Bit Error Rate (BER) tests. The test data was collected from two UAT receivers configured to simultaneously operate under the same received signal conditions. The two receivers differed in the design of their front-end receiver bandwidth.

Originally, the JSC objective was only to support the MER and BER tests by providing JTIDS and DME signals. However, at the beginning of the MITRE-defined MER tests, it was recognized that existing JSC lab hardware/software capabilities could be used to aid in the collection of the MER data. The BER data collection, presentation, and analysis remained under APL control.

The UAT test effort was conducted at the JSC in Annapolis, MD, during September and October of 2001. Organizations supporting the test effort included MITRE/Boston, MITRE/Washington, and JHU Applied Physics Lab/Baltimore.

MER TEST EFFORT

During the MER testing, the UAT message success rate (MSR) was measured. The MSR is defined as the ratio of the number of messages decoded by the receiver to the number of messages transmitted by the transmitter. The MSR performance was measured in the air-to-air and ground-to-air modes using DME and JTIDS interference test conditions with desired UAT signal levels of sensitivity plus 6 dB and sensitivity plus 30 dB.

The MER test matrix was defined by MITRE. The MER test matrix included baseline (no DME or JTIDS pulses present) sensitivity tests plus interference tests for both air-to-air and ground-to-air modes. The baseline sensitivity of the UAT was defined to be the received signal level at which the UAT could produce a MSR of ninety percent. Once the baseline sensitivity was established, interference tests were performed at sensitivity plus 6 dB and sensitivity plus 30 dB with various DME and JTIDS environments. Baseline sensitivity tests were performed with the UAT Forward Error Correction (FEC) on and off. All interference tests were performed with the FEC on. All tests were repeated three times to verify the consistency of the data. The MER test matrix is shown in Table 1.

MER Test Setup

The test setup for MER tests is shown in Figure 1. Two separate UAT receivers were tested. One receiver had a receiver 3-dB bandwidth of 1.2 MHz and the other UAT had a receiver bandwidth of 0.8 MHz. Both units had a tuned receiver frequency of 981 MHz. Testing on the two receivers was performed simultaneously.

The MER test setup also included a third UAT unit which was used as a desired signal source transmitter. The transmitter was specifically configured to transmit thirty-two random data bit messages per second to support these UAT tests. A normal UAT unit transmits only one message per second with the message data defined by the information transmitted.

The UAT transmitter output was attenuated by at least 80 dB to bring it closer to the receiver's sensitivity levels. Additional programmable attenuation was used to set the UAT transmission message level at the UAT receivers. The RF path losses to each UAT receiver were the same, thus the transmission signal arrived at both UAT receivers at the same level. The UAT transmitter unit had been modified to provide an output synchronous with the RF transmission output. Both UAT receivers had also been modified to provide an output synchronous with received transmissions. These three "sync" signals were input to three computer-controlled counters. The three counters shared a common gate and only counted "sync" pulses when the computer set the gate signal. It was desired to collect MSR data based on 1000 transmission samples. To achieve 1000 samples, for the air-to-air mode, the gate length was set to 31.25 seconds (32 transmissions per second), and for the ground-to-air mode, the gate length was set to 142.86 seconds (7 transmissions per second). The data collection setup was automated by a computer to maximize time efficiency and data repeatability.

Table 1. MER Test Matrix for Air-to-Air and Ground-to-Air Modes

Test Description	UAT Signal Level (dBm)	FEC	JTIDS Environment	DME Environment
Baseline Sensitivity	-85 thru -95	Off	None	None
Baseline Sensitivity	-90 thru -100	On	None	None
JTIDS Test	Sens. + 6 dB	On	100% TSDF at -90,-80, -70,-60,-50,-40,-30 dBm	None
JTIDS Test	Sens. + 30 dB	On	100% TSDF at -90,-80, -70,-60,-50,-40,-30 dBm	None
JTIDS Test	Sens. + 6 dB	On	200% TSDF at -90,-80, -70,-60,-50,-40,-30 dBm	None
JTIDS Test	Sens. + 30 dB	On	200% TSDF at -90,-80, -70,-60,-50,-40,-30 dBm	None
DME Test	Sens. + 6 dB	On	None	One DME source at 3600 ppps,[a] 12 µs spacing, 982 MHz, at -90, -80, -70, -60, -50, -40, -30 dBm
DME Test	Sens. + 30 dB	On	None	One DME source at 3600 ppps, 12 µs spacing, 982 MHz, at -90, -80, -70, -60, -50, -40, -30 dBm
DME Test	Sens. + 6 dB	On	None	Two DME sources each with 3600 ppps, 12 µs spacing, 982 MHz, at -90, -80, -70, -60, -50, -40, -30 dBm
DME test	Sens. + 30 dB	On	None	Two DME sources each with 3600 ppps, 12 µs spacing, 982 MHz, at -90, -80, -70, -60, -50, -40, -30 dBm

[a]ppps = pulse pairs per second

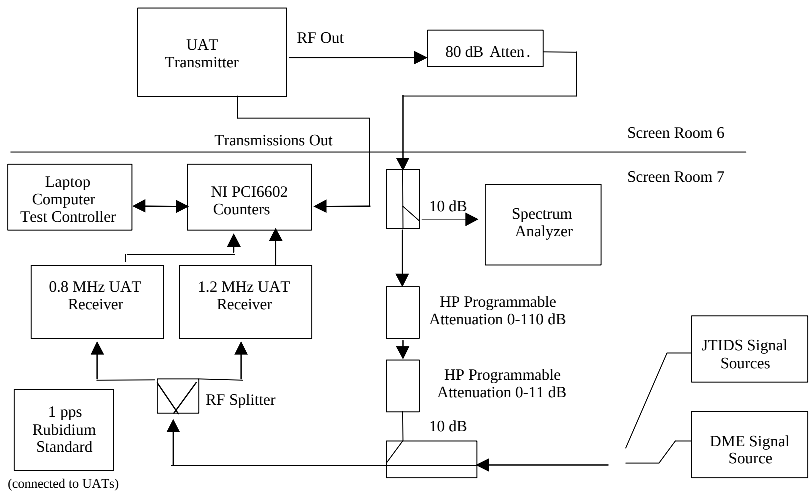

Figure 1. UAT MER Test Setup

JTIDS Environment

The JTIDS environment used during the MER tests were 100% Time Slot Duty Factor (TSDF) and 200% TSDF scenarios. In these scenarios, JTIDS operated in a normal fashion such that the pulses within a time slot randomly hopped on the 51 different JTIDS frequencies. During a JTIDS test, the JTIDS signal level was varied from -90 dBm (with respect to receiver UAT input) to -30 dBm in 10 dB increments. All JTIDS signal levels were the same at any given point in time (i.e., either all pulses were -90 dBm, or all pulses were -80 dBm, etc.). The 100% TSDF scenario was generated by one JTIDS source. The 200% TSDF scenario was generated by two JTIDS sources, each operating at 100% TSDF and hopping on a separate net. It can be noted that both of these scenarios exposed the UAT to a more severe JTIDS environment than could exist at a UAT receiver in the real world.

DME Environment

Two separate DME environments were used during the MER tests. The first DME environment consisted of a single RF source transmitting 3600 (exponentially distributed) DME N shaped pulse pairs per second (spacing = 12 μs) at a frequency of 982 MHz. This frequency was +1 MHz from the UAT receiver frequency of 981 MHz. The second DME environment consisted of two RF sources, each transmitting the above-mentioned environment. For this dual-source environment, each RF source was independent of the other, thus the pulse pairs of one source were not in time synchronization with the other source. The signal level of the DME environments was varied from -90 dBm (with respect to receiver UAT input) to -30 dBm in 10 dB increments. It can be noted that both DME environments exposed the UAT receivers to severe pulse density and signal level DME scenarios.

BER TEST EFFORT

During the BER tests, the bit errors contained within received UAT messages were measured. These were determined by comparing data bits in the messages that were transmitted with data bits in the messages that were received using a sample size of 10^6 bits. The BER test data was collected using a range of desired signal-to-interference level ratios.

The BER test approach was defined by personnel from the Johns Hopkins Applied Physics Laboratory. The purpose of the BER tests was to measure the bit error rate of the UAT receiver in the presence of DME and JTIDS environments. The BER test setup required the synchronization of DME or JTIDS pulses (depending on the type of test) to occur at key positions during the UAT transmitted message.

BER Test Setup

APL provided a PC-based “BER test fixture” designed to collect UAT transmit and receive reports for up to two UAT receivers, perform and display BER computations in real time, and store the calculated BER to disk for off-line processing and analysis. This BER setup tested both the 1.2 MHz UAT and the 0.8 MHz UAT simultaneously. The BER test setup is shown in Figure 2.

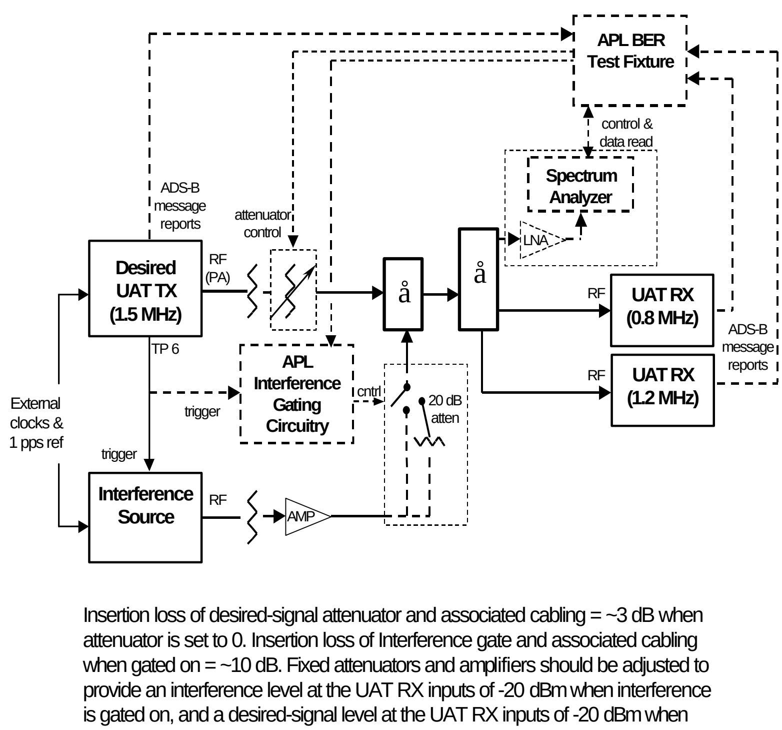

Figure 2. BER Test Setup

BER Due To DME

To reduce data storage requirements and shorten test time, multiple DME pulse pairs occurred during each UAT message. The DME pulse pair (12 µs spacing) repetition rate was approximately 30 kHz (33.3 µs spacing) during the UAT message. The pulse pairs were delayed approximately 45 µs from the start of the transmitted message to prevent overlap with the UAT synchronization header, which could possibly prevent message reception. For these tests, all the DME pulse pairs were either at 982 MHz (+1 MHz off UAT channel) or at 981 MHz. The maximum DME signal level at the UAT required for these tests was -20 dBm. Figure 3 shows the DME pulse pairs with respect to the UAT transmitted message.

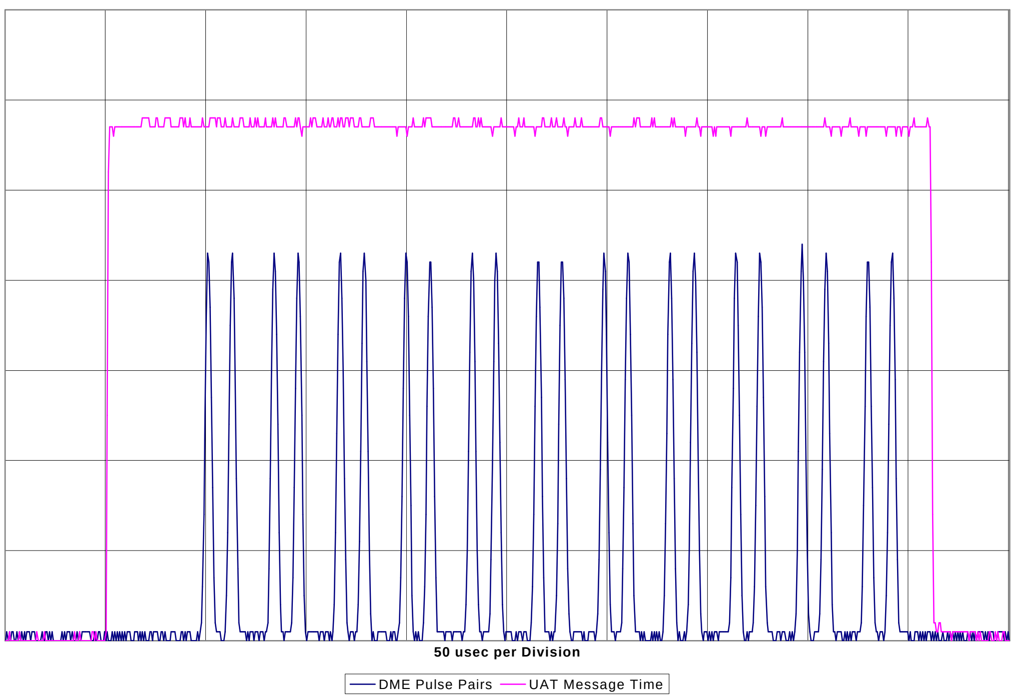

Figure 3. DME Pulse Pairs Synchronous with UAT Message Transmission

To establish an accuracy of less than 10^{-4}, BER was measured using a sample of 10^6 bits. There were 11 DME pulse pairs per UAT transmitter message (see Figure 3.), with 32 UAT messages per second, thus each test required approximately 50 minutes to collect the 10^6 bits.

BER Due To JTIDS

The BER test setup required time synchronization and frequency control of JTIDS pulses with the transmitted UAT message.

The JTIDS pulses were only transmitted on two frequencies (instead of the normal mode where JTIDS pulses hop on 51 different frequencies). For each JTIDS timeslot, the individual pulse frequencies alternated between the two frequencies. The frequency of the first pulse of the timeslot was assigned to the test control frequency. The frequency of the second pulse of the timeslot was 1053 MHz, which was selected because it was far removed from the UAT receiver frequency and was used for all the tests. The test control frequencies that accompanied 1053 MHz were 981 MHz (UAT on tune), 984 MHz, 987 MHz, 990 MHz, 993 MHz, and 996 MHz. Having every other pulse transmitted on 1053 MHz resulted in the “on-tune” JTIDS pulses occurring every 26 µs (JTIDS pulses transmit every 13 µs).

The JTIDS pulses were specially triggered to occur during the UAT message transmission. The JTIDS pulses were delayed approximately 50.0 µs from the start of the UAT message to prevent overlap with the UAT synchronization header, which could possibly prevent message reception. The maximum JTIDS signal level at the UAT required for these tests was -20 dBm. Figure 4 shows the timing of the JTIDS pulses with respect to the UAT transmitted message.

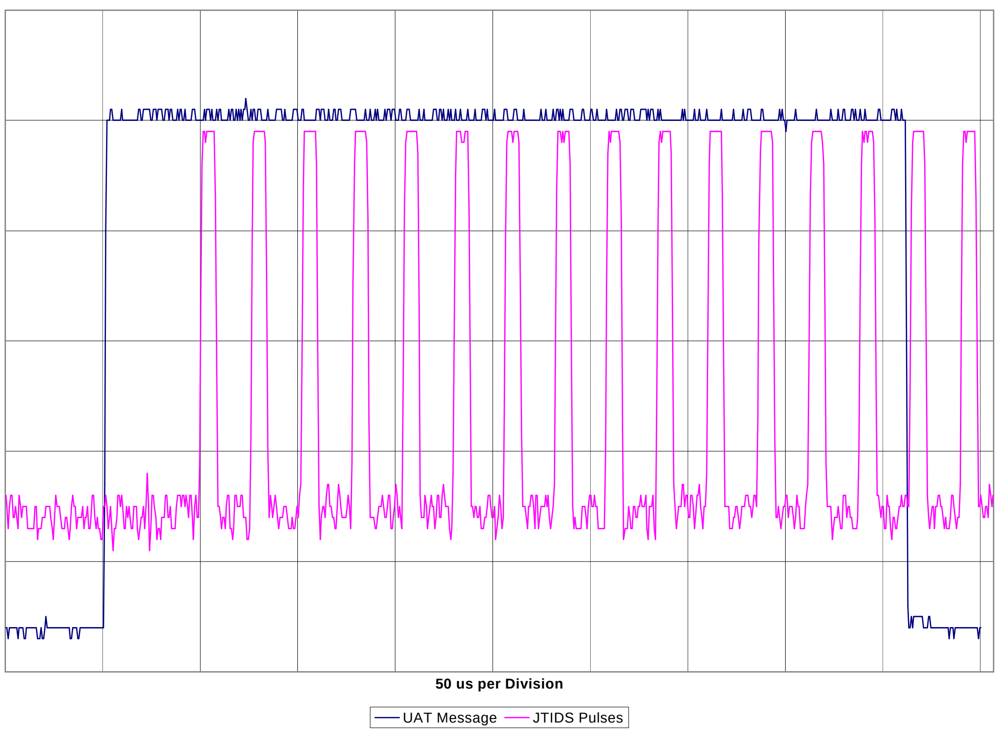

Figure 4. JTIDS Pulses Synchronous with UAT Message Transmission

RESULTS

MER Results

Figures 5 through 24 show the MSR data for the 0.8 MHz and the 1.2 MHz UAT operating in air-to-air and ground-to-air modes. Each MSR measurement was based on 1000 transmitted UAT messages. Each test was repeated three times to verify data consistency, and since there were two units tested, this corresponds to six curves per figure.

The baseline sensitivity for both the 0.8 MHz and the 1.2 MHz UAT with FEC on was -97 dBm in air-to-air mode, and -95 dBm in ground-to-air-mode. The baseline sensitivity with FEC off for the 0.8 MHz UAT was -91 dBm operating in air-to-air mode and -89 dBm operating in ground-to-air mode. The baseline sensitivity with FEC off for the 1.2 MHz UAT was -93 dBm operating in air-to-air mode and -91 dBm operating in ground-to-air mode. Figures 5 through 8 show the baseline data.

The 0.8 MHz and the 1.2 MHz UAT MSR performance operating in air-to-air and ground-to-air modes in the presence of 100% TSDF JTIDS signals is shown in Figures 9 through 12. The 0.8 MHz and the 1.2 MHz UAT MSR performance operating in air-to-air and ground-to-air modes in the presence of 200% TSDF JTIDS signals is shown in Figures 13 through 16. For all of these tests, the FEC was on and the message signal level was sensitivity plus six dB or sensitivity plus thirty dB.

The 0.8 MHz and the 1.2 MHz UAT MSR performance operating in air-to-air and ground-to-air modes in the presence of a single source DME environment is shown in Figures 17 through 20. The 0.8 MHz and the 1.2 MHz UAT MSR performance operating in air-to-air and ground-to-air modes in the presence of a dual source DME environment is shown in Figures 21 through 24. For all of these tests the FEC was on, and the message signal level was sensitivity plus six dB or sensitivity plus thirty dB.

BER Results

The BER test data was collected by the JHU PC-based “BER test fixture” and stored on a computer as unprocessed data in binary formatted data files. Although the JSC team provided DME/JTIDS and RF setup support for BER testing, the BER data was not provided to the JSC team for processing.

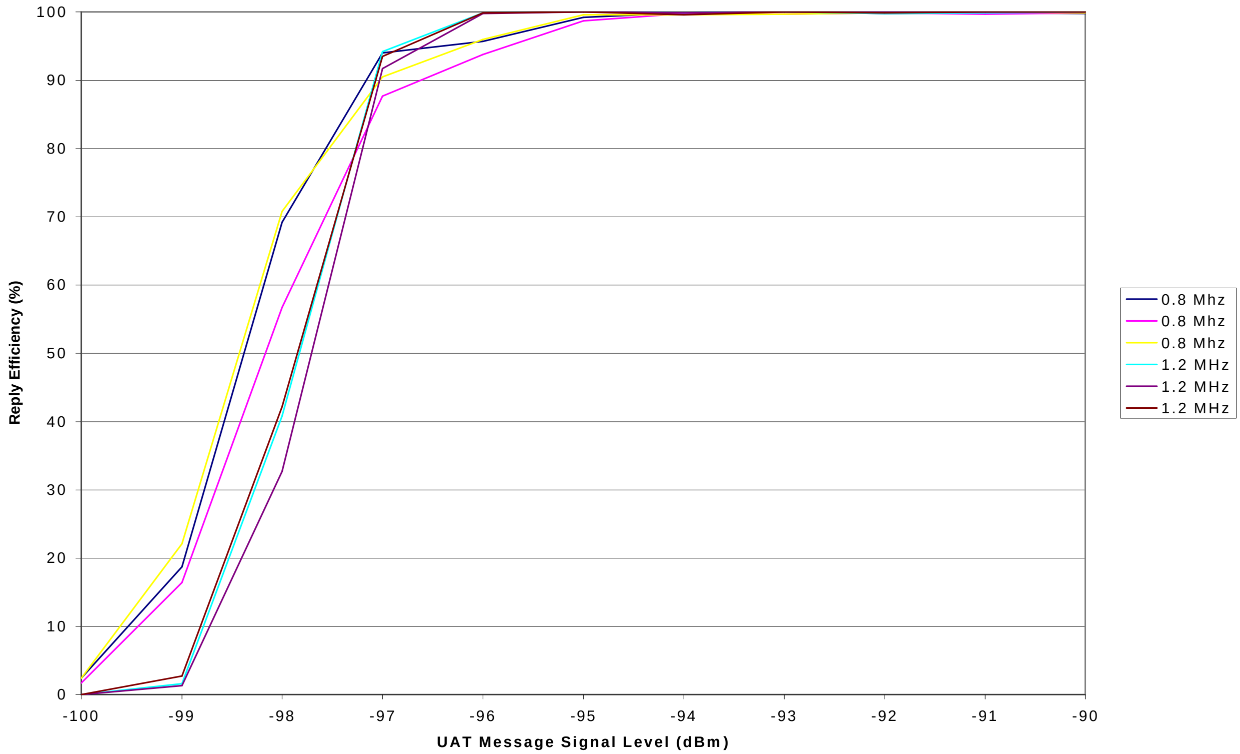

Figure 5. UAT Baseline MSR (FEC on) for Air-to-Air Mode (0.8 and 1.2 MHz Receivers)

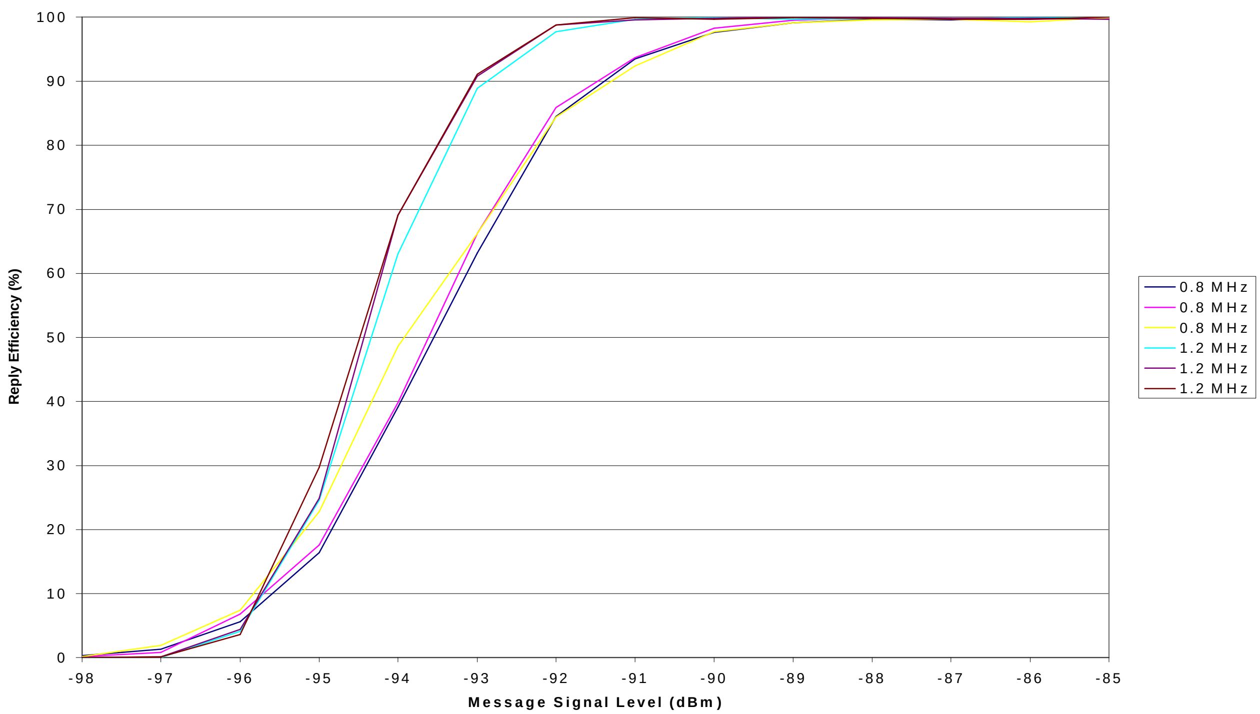

Figure 6. UAT Baseline MSR (FEC off) for Air-to-Air Mode (0.8 and 1.2 MHz Receivers)

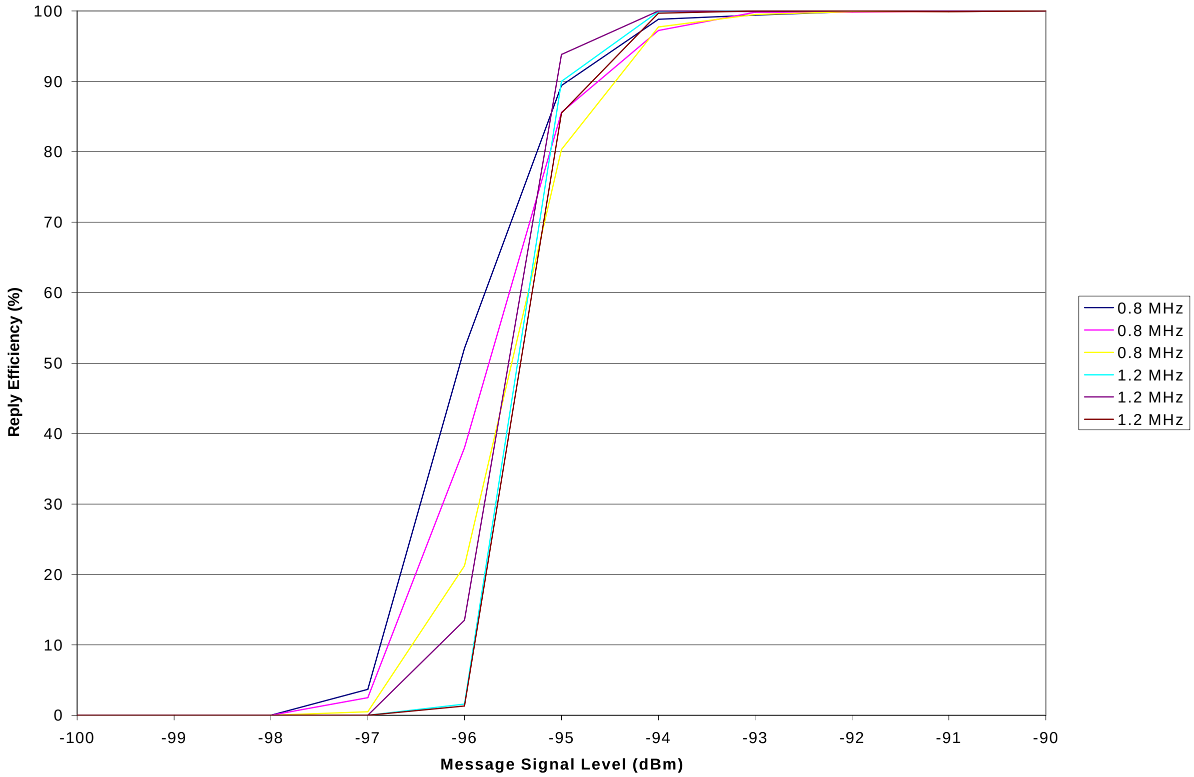

Figure 7. UAT Baseline MSR (FEC on) for Ground-to-Air Mode (0.8 and 1.2 MHz Receivers)

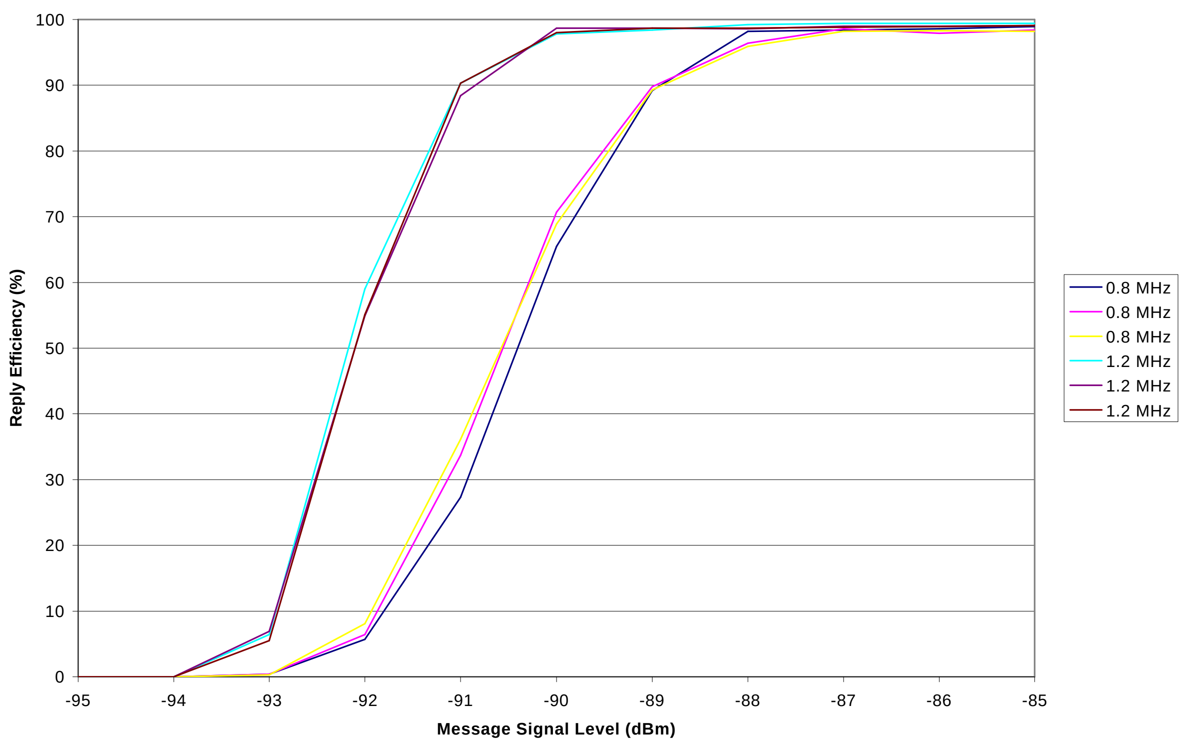

Figure 8. UAT Baseline MSR (FEC off) for Ground-to-Air Mode (0.8 and 1.2 MHz Receivers)

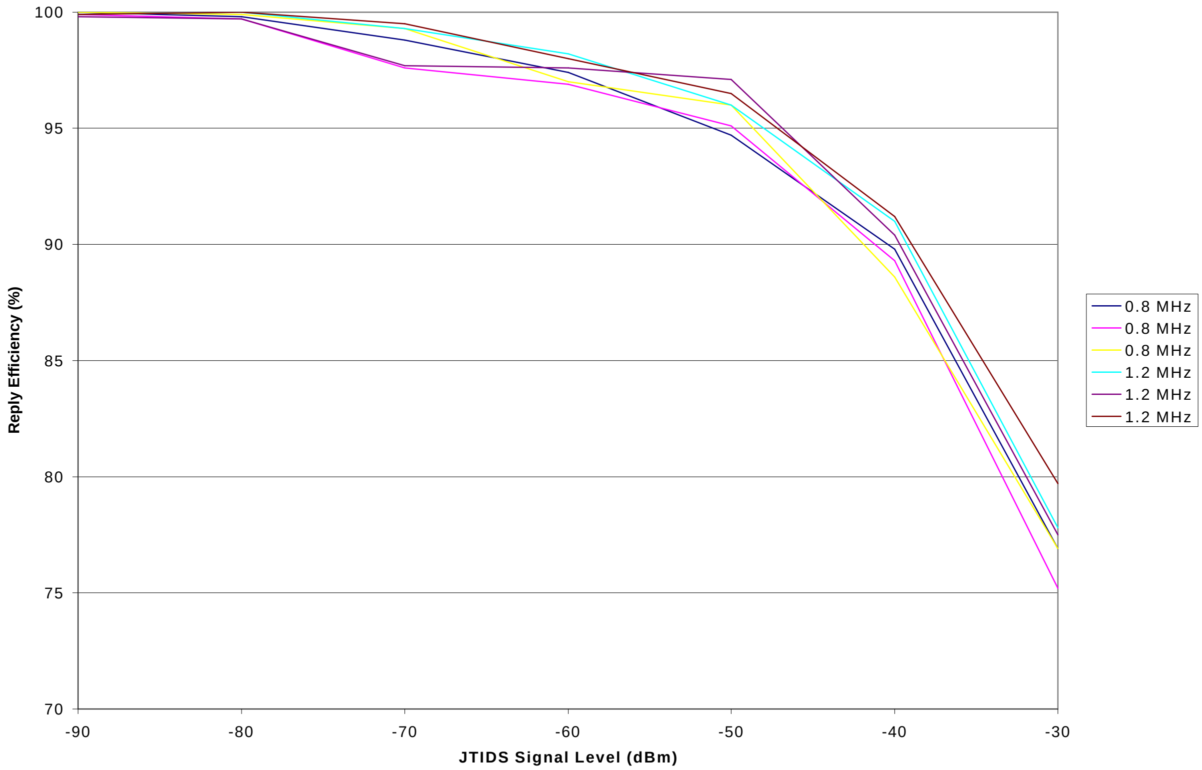

Figure 9. UAT MSR at Sensitivity plus 6 dB in Air-to-Air Mode with 100% TSDF JTIDS (0.8 and 1.2 MHz Receivers)

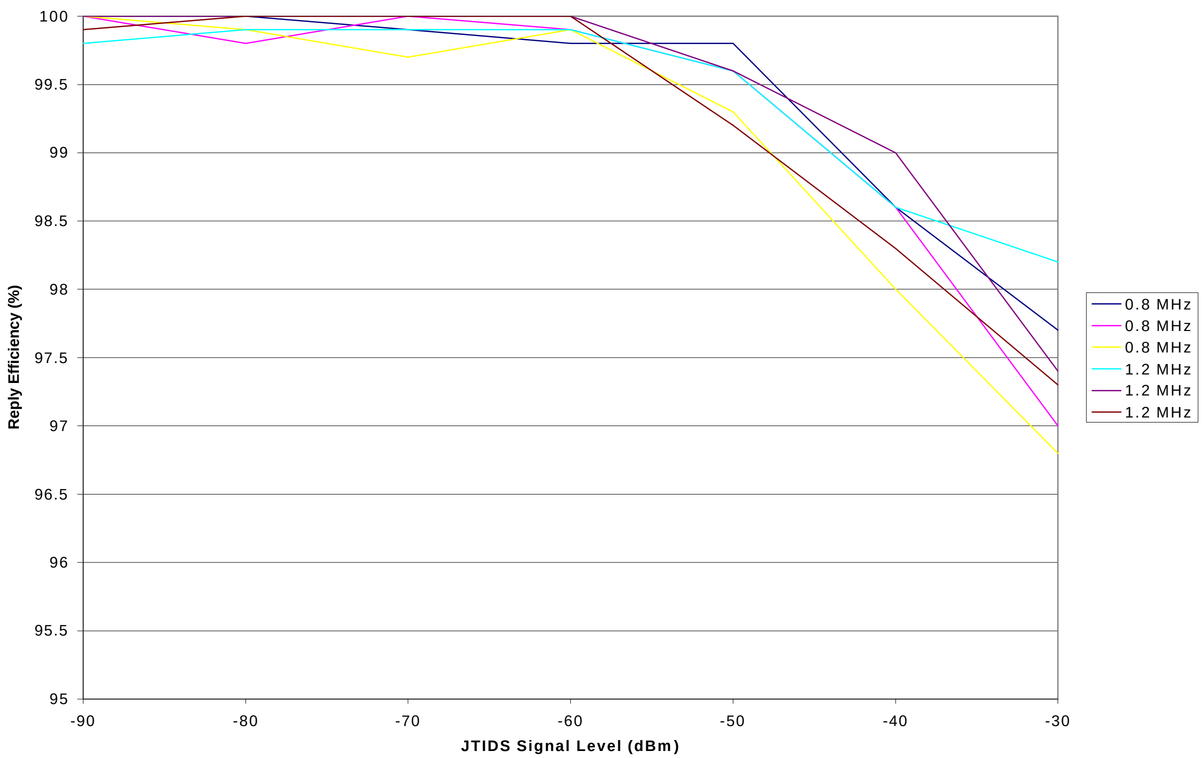

Figure 10. UAT MSR at Sensitivity plus 30 dB in Air-to-Air Mode with 100% TSDF JTIDS (0.8 and 1.2 MHz Receivers)

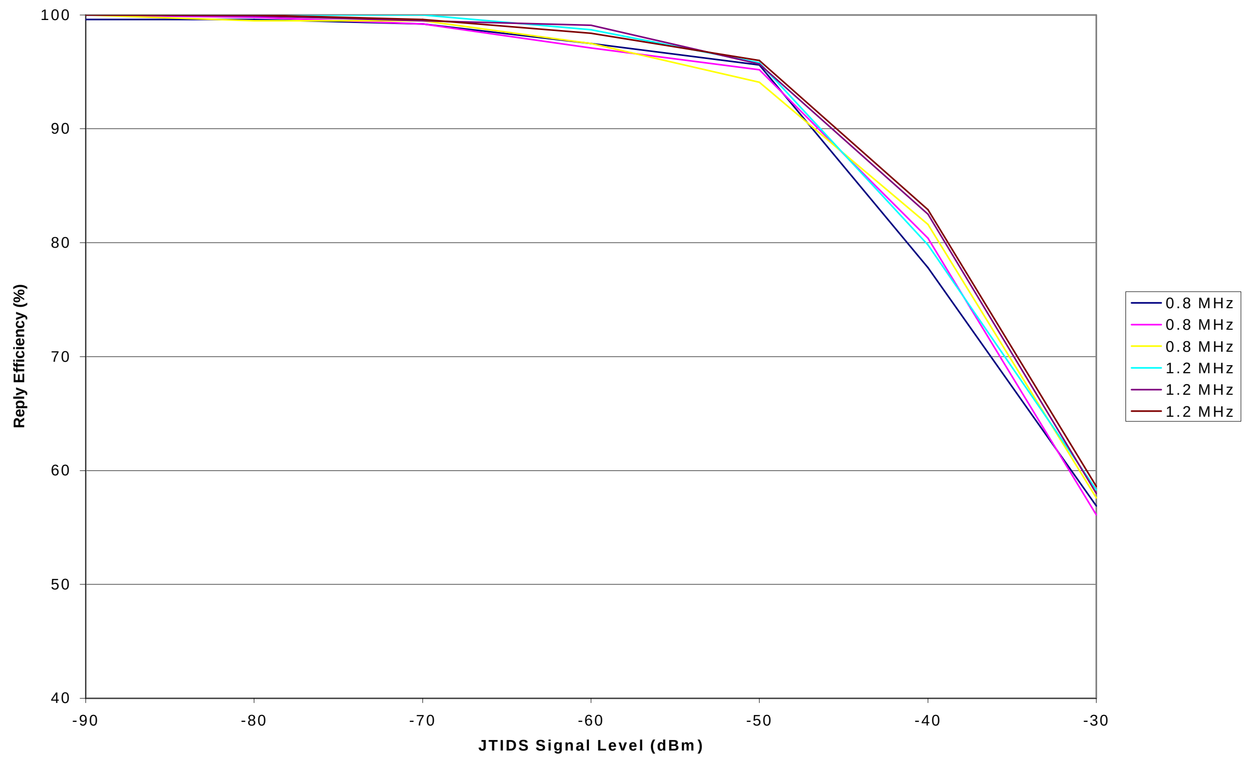

Figure 11. UAT MSR at Sensitivity plus 6 dB in Ground-to-Air Mode with 100% TSDF JTIDS (0.8 and 1.2 MHz Receivers)

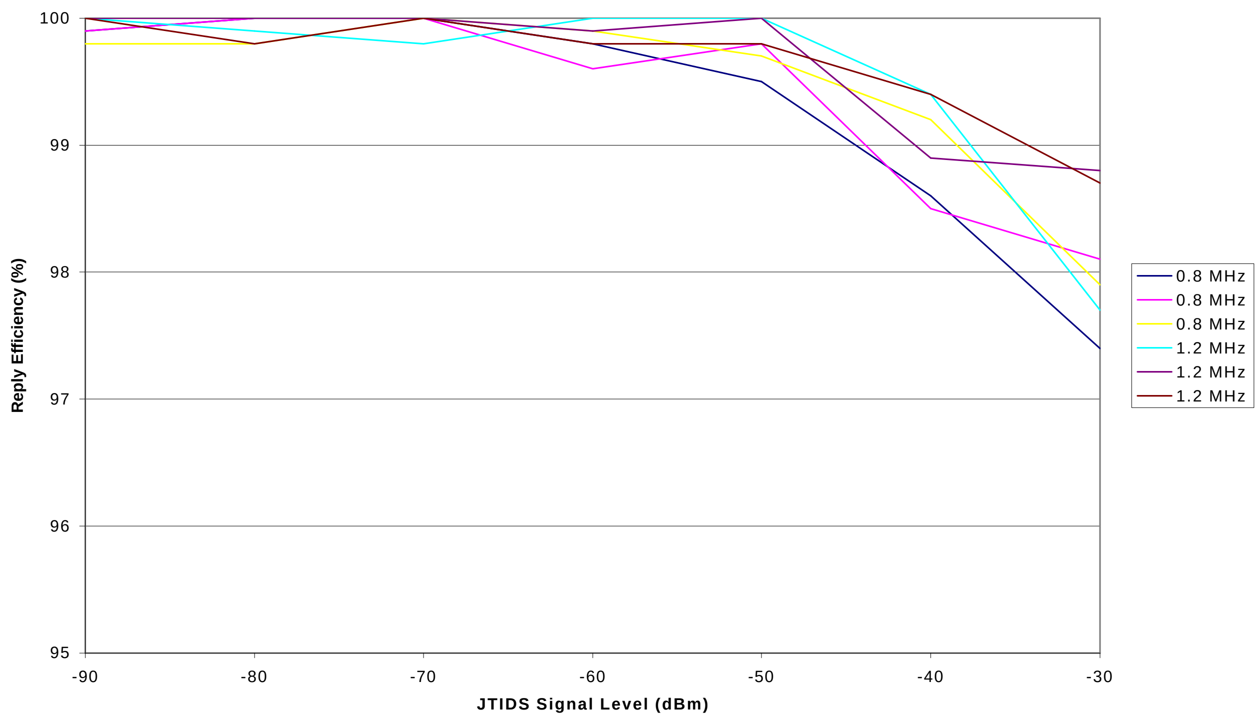

Figure 12. UAT MSR at Sensitivity plus 30 dB in Ground-to-Air Mode with 100% TSDF JTIDS (0.8 and 1.2 MHz Receivers)

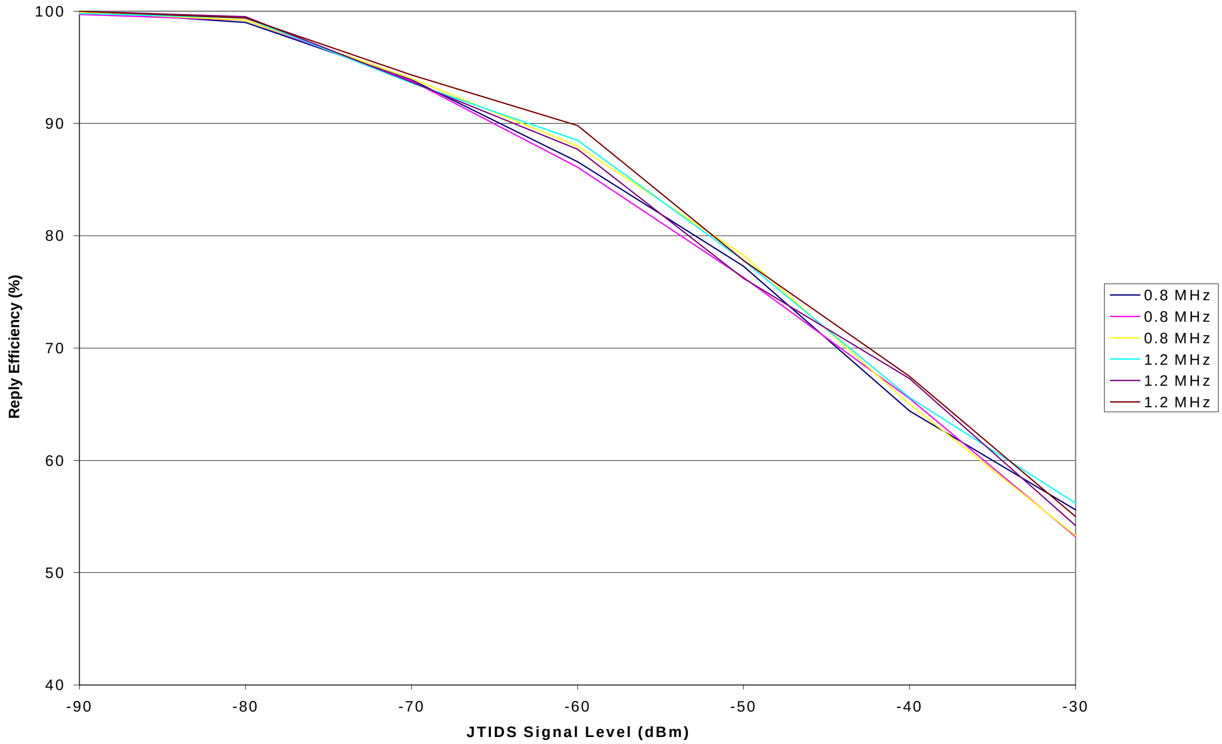

Figure 13. UAT MSR at Sensitivity plus 6 dB in Air-to-Air Mode with 200% TSDF JTIDS (0.8 and 1.2 MHz Receivers)

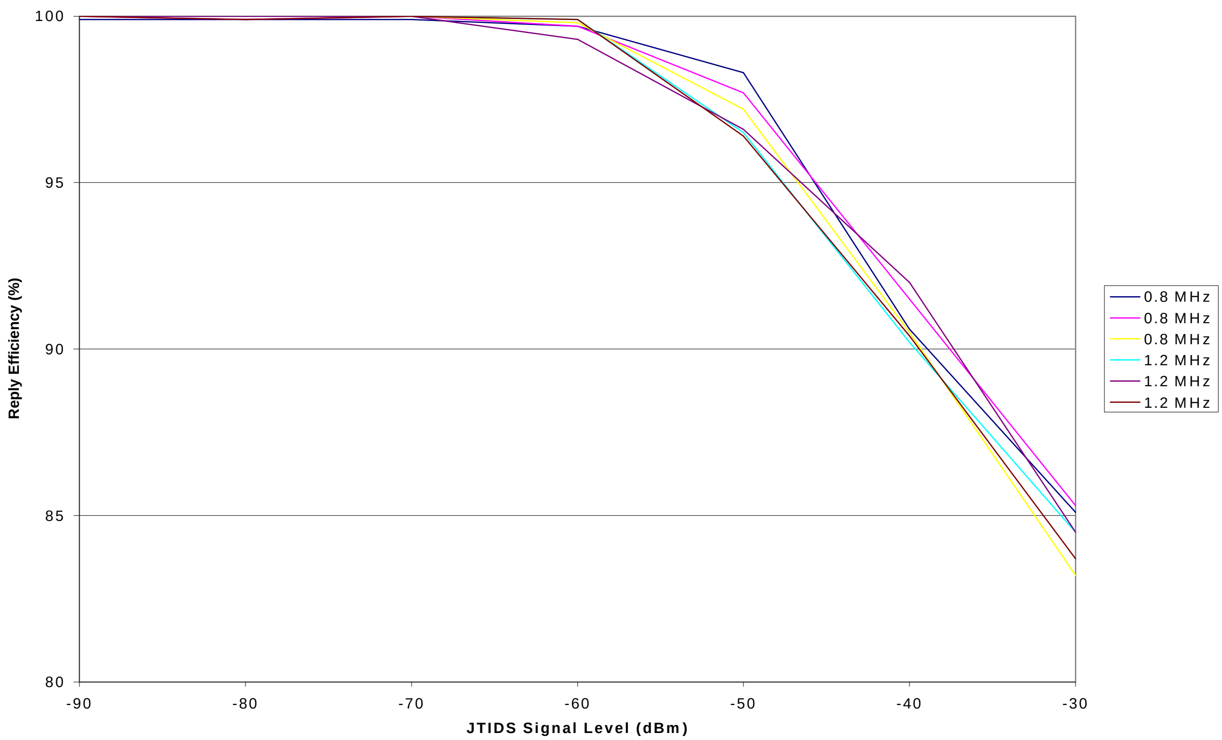

Figure 14. UAT MSR at Sensitivity plus 30 dB in Air-to-Air Mode with 200% TSDF JTIDS (0.8 and 1.2 MHz Receivers)

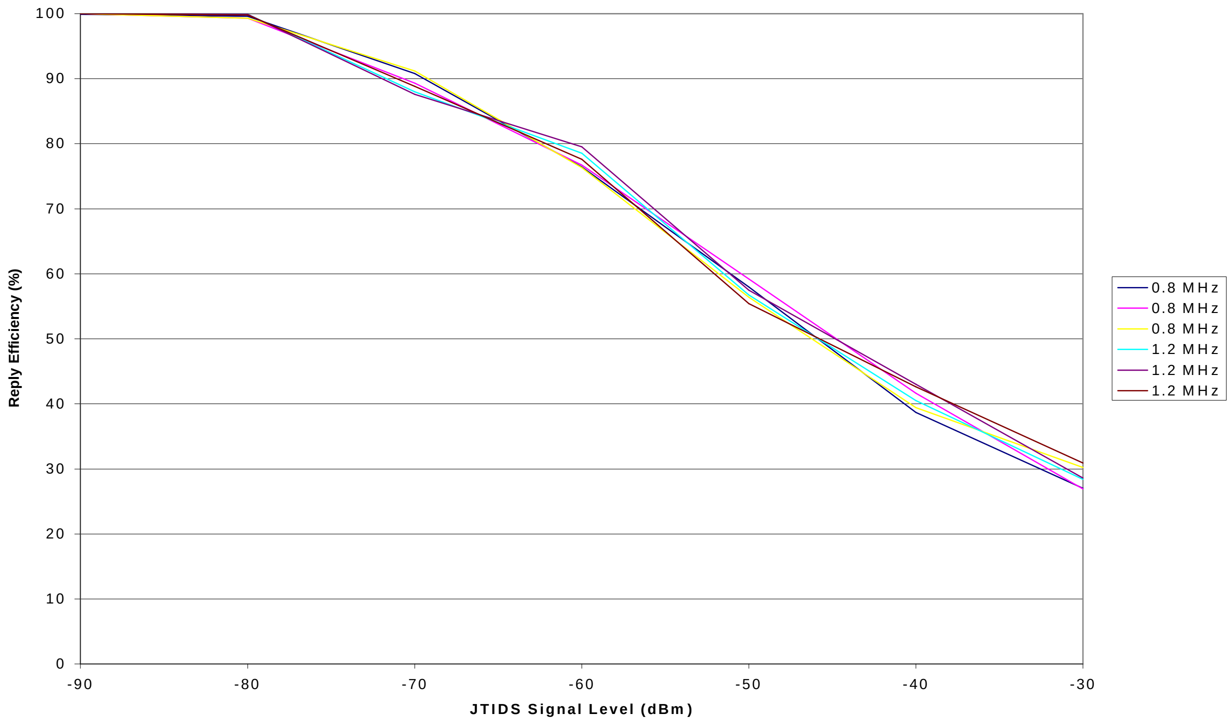

Figure 15. UAT MSR at Sensitivity plus 6 dB in Ground-to-Air Mode with 200% TSDF JTIDS (0.8 and 1.2 MHz Receivers)

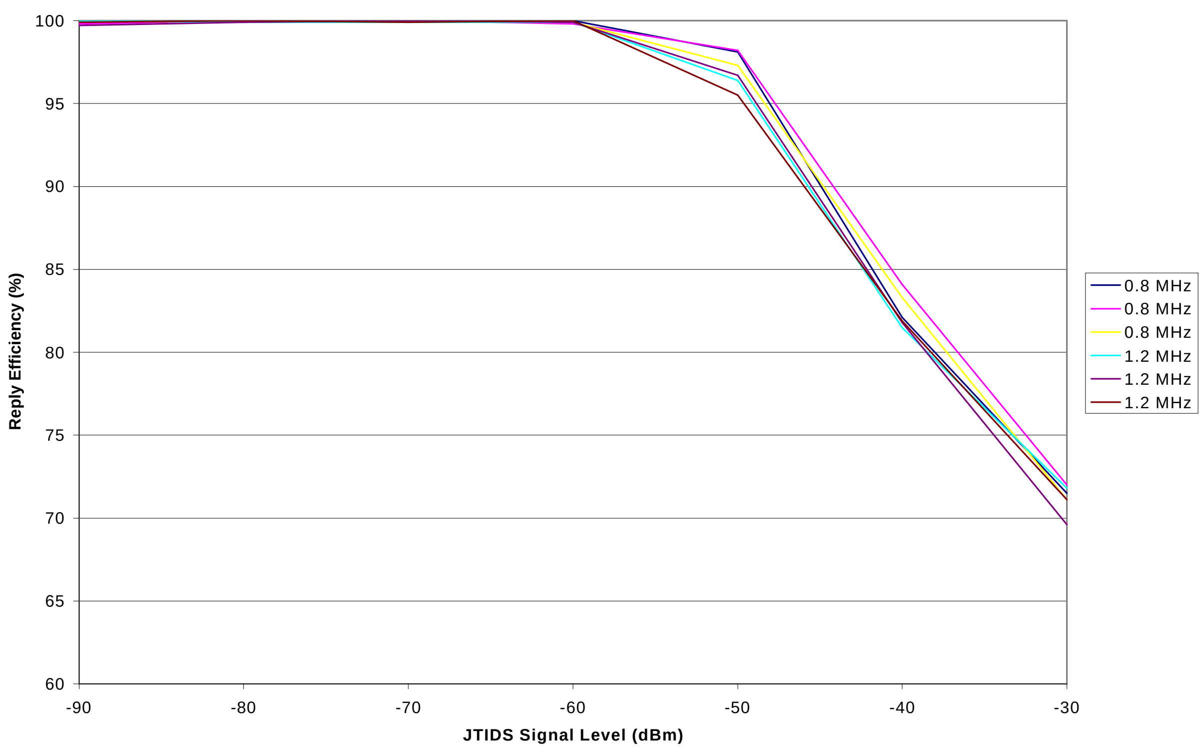

Figure 16. UAT MSR at Sensitivity plus 30 dB in Ground-to-Air Mode with 200% TSDF JTIDS (0.8 and 1.2 MHz Receivers)

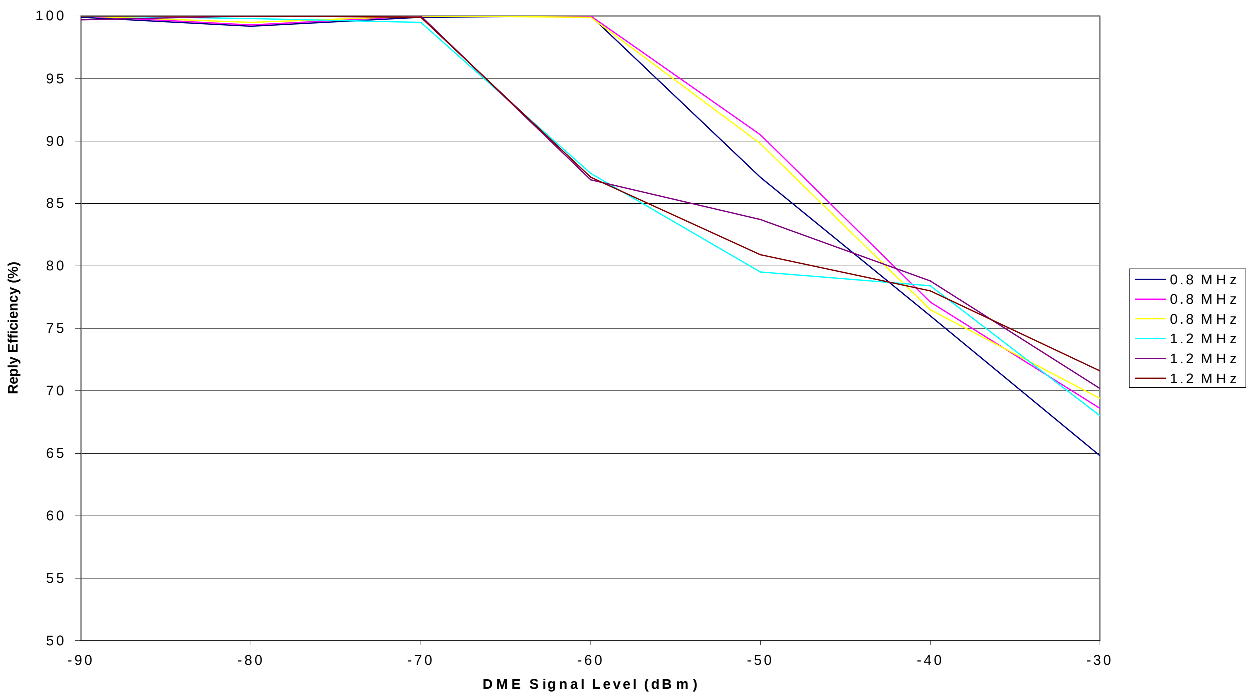

Figure 17. UAT MSR at Sensitivity plus 6 dB in Air-to-Air Mode with One DME Source Transmitting 3600 ppps (0.8 and 1.2 MHz Receivers)

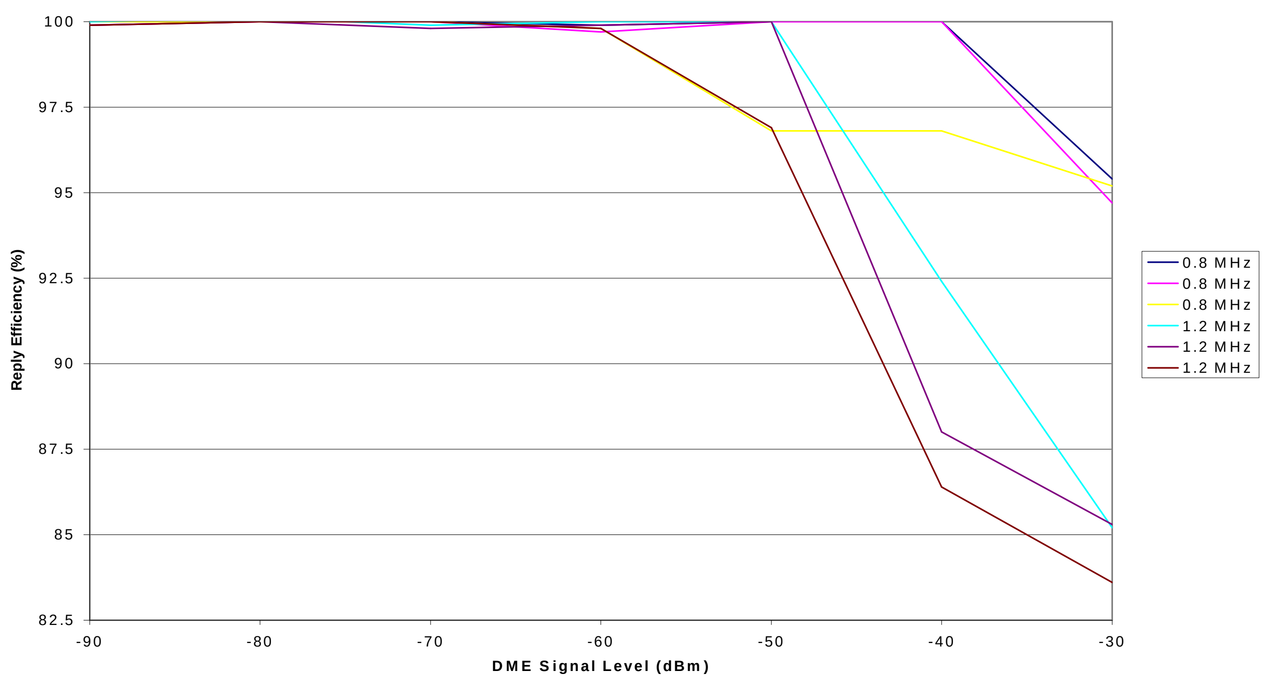

Figure 18. UAT MSR at Sensitivity plus 30 dB in Air-to-Air Mode with One DME Source Transmitting 3600 ppps (0.8 and 1.2 MHz Receivers)

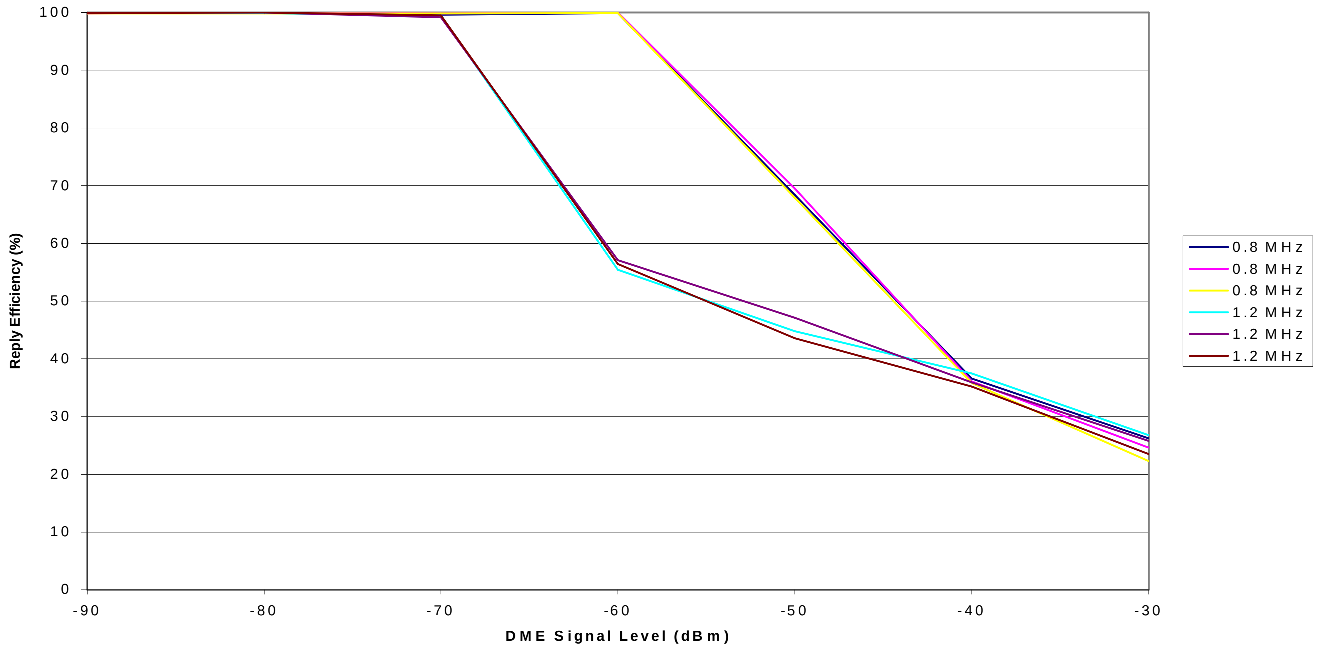

Figure 19. UAT MSR at Sensitivity plus 6 dB in Ground-to-Air Mode with One DME Source Transmitting 3600 ppps (0.8 and 1.2 MHz Receivers)

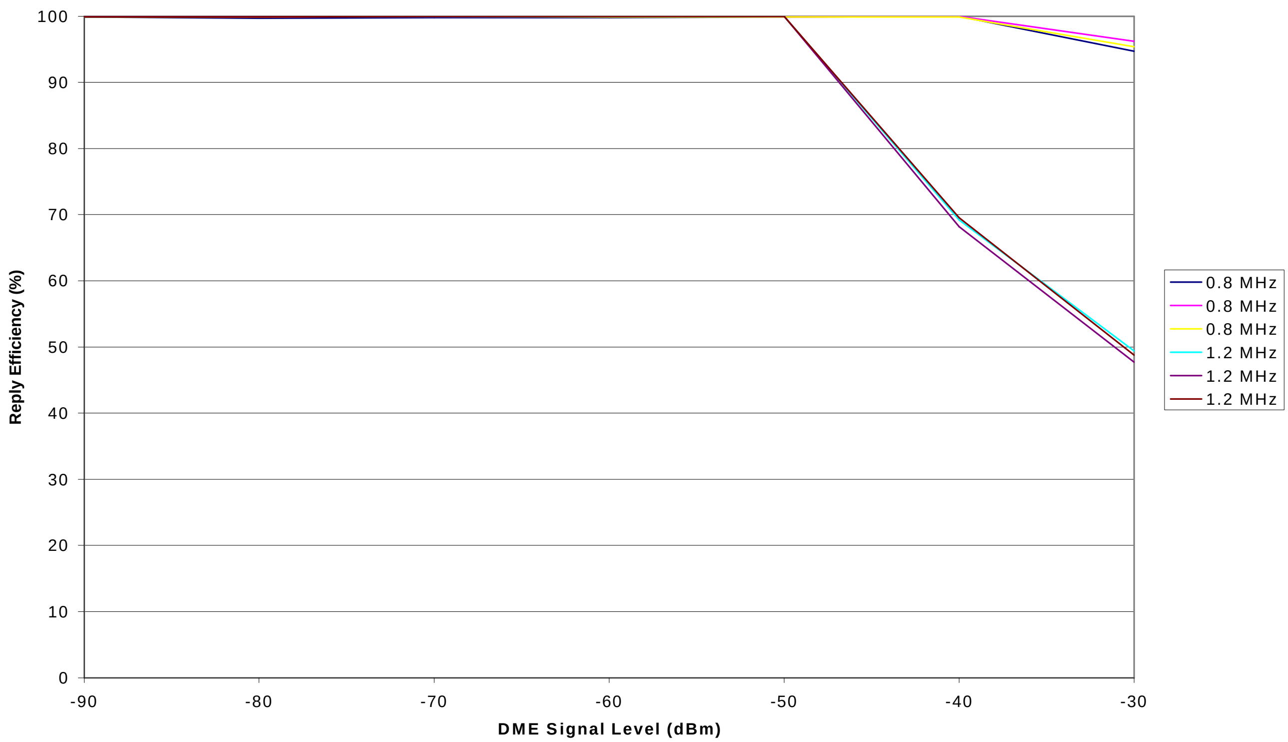

Figure 20. UAT MSR at Sensitivity plus 30 dB in Ground-to-Air Mode with One DME Source Transmitting 3600 ppps (0.8 and 1.2 MHz Receivers)

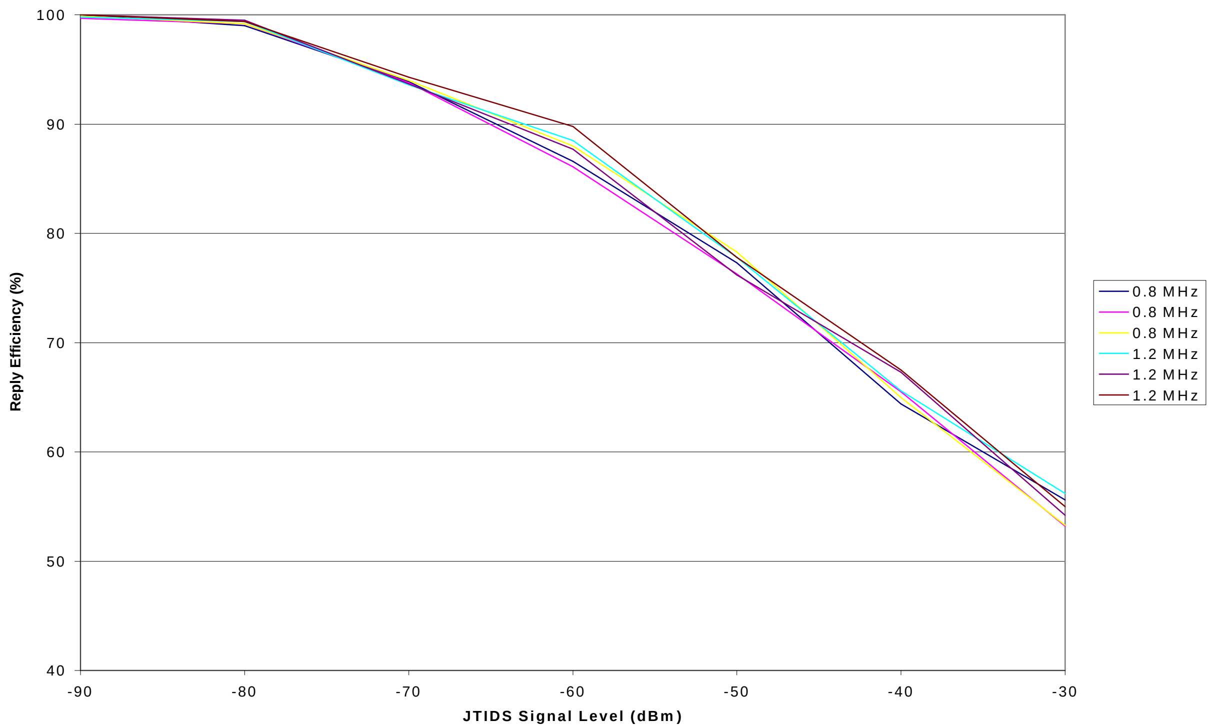

Figure 21. UAT MSR at Sensitivity plus 6 dB in Air-to-Air Mode with Two DME Sources each Transmitting 3600 ppps (0.8 and 1.2 MHz Receivers)

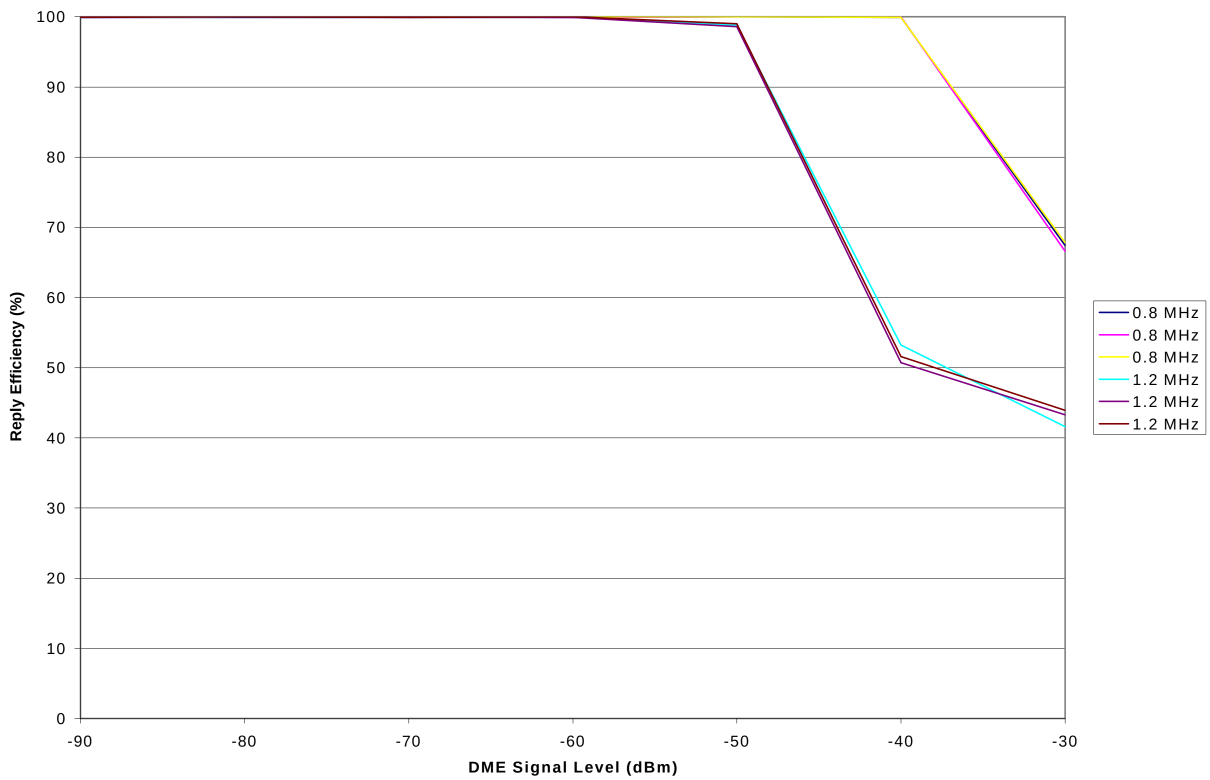

Figure 22. UAT MSR at Sensitivity plus 30 dB in Air-to-Air Mode with Two DME Sources each Transmitting 3600 ppps (0.8 and 1.2 MHz Receivers)

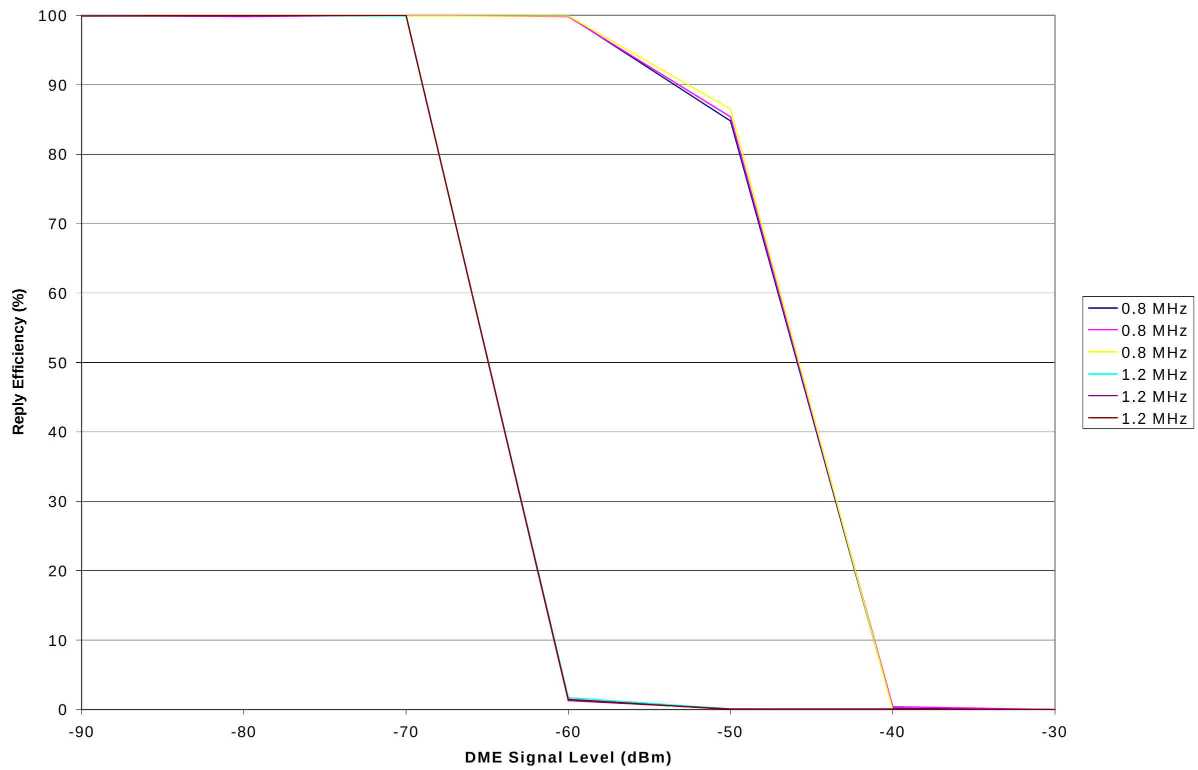

Figure 23. UAT MSR at Sensitivity plus 6 dB in Ground-to-Air Mode with Two DME Sources each Transmitting 3600 ppps (0.8 and 1.2 MHz Receivers)

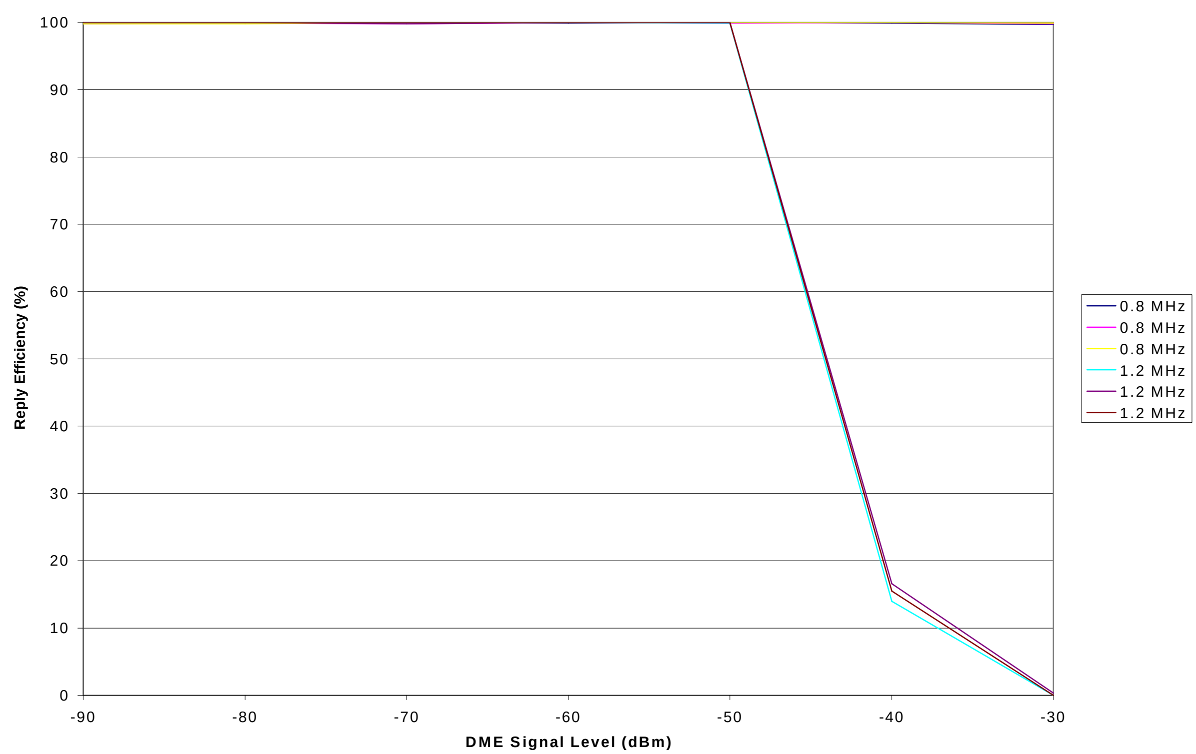

Figure 24. UAT MSR at Sensitivity plus 30 dB in Ground-to-Air Mode with Two DME Sources each Transmitting 3600 ppps (0.8 and 1.2 MHz Receivers)